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The Properties of Quartz Thermoluminescence Dosimeters

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The present investigation was undertaken as a preliminary experiment on quartz as a thermoluminescence dosimeter. The glow curve resulting from natural Brazilian quartz showed three glow peaks at approximately 110°C, 220°C and 310°C. It has been found that the second peak of the three is the most desirable one from a view-point of dosimetry in the case of an accident. In the case of normal dosimetry the susceptibility of quartz for radio-thermoluminecence could be increased by the irradiation with Co^{60} gamma rays on a large scale (1×10^7r). This dosimeter had the advantage of low fading because of the high peak-temperature (280°C) and of excellent linearity to the absorbed dose to 1×10^4r at least.

INTRODUCTION

Since in many crystals the intensity of thermoluminescence is nearly proportional to the amount of gamma radiation received, thermoluminescence has been studied in recent years by several groups of workers from a stand point of dosimetry. From the results of these studies synthetic crystals of manganese-activated calcium fluoride[1)], calcium sulfate[2)] and lithium fluoride have been found to be especially suitable for this purpose, and they had the advantage of high sensitivity and excellent linearity to the absorbed dose.

On the other hand, some natural substances have been used to find the radiation absorbed by the samples in the past, such as limestone in the determination of the geologic age of carbonate sediments[3)], and dating of ancient pottery by thermoluminescence is now in progress[4)]. We attempted also to estimate the atomic bomb radiation of twenty years ago, making use of roof tiles as phosphor irradiated by the gamma rays from the bombs in Hiroshima and Nagasaki[5)], and succeeded in it by employing the sample preparation technique of washing and separation of the grain[6)]. When the samples were separated into colorless mineral and colored mineral by means of a magnetic separator the thermoluminescence sensitivity of the former was higher than that of the latter, and showed the type of the glow curve answering our purpose as thermoluminescences phosphor. Although the roof tiles consisted of various minerals and amorphous substances, colorless minerals contained much quartz and the sensitivity of them was so excellent that a bomb dose below 100r could be measured.

On the basis of these facts, it seemed reasonable to assume that quartz can sufficiently act as the part of thermoluminescence phosphor for measurement of the absorbed dose in the past as well as in the present. The present investiga-

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tion was undertaken to examine thermoluminescence properties of quartz from a view-point of dosimetry. Since quartz is ordinary substance which can easily be found everywhere, it can be used in the case of an accident of a nuclear reactor, and so on.

METHOD OF MEASUREMENTS

The apparatus used for the measurements is the same as described in the previous report[7] on the measurement of the absorbed dose from the atomic bombs; it is composed of a furnance with silver hot-plate, a photomultiplier (Toshiba 7696) with $2''\phi$, a d.c. amplifier ($2\times10^{-6}\sim1\times10^{-9}$A) and a two-pen recorder. The two-pen recorder is used to record the glow intensity and the temperature of the samples simultaneously in order to simplify the data processing. The thermocouple used is alumel-chromel. The distance between the hot-plate on which the samples are placed and the photomultiplier is about 10 cm and in order to assure efficient light transmission, and they are connected by a light-pipe which is equipped with an IR-filter to screen the thermal radiation and a shutter for use when samples are replaced.

Sample used as phosphor for measurements was mainly a large single crystal of Brazilian quartz. This sample was ground with an agate mortar and then the grains were sieved so that the grains of size of 100～200 mesh were obtained. Glow curves which express intensity as a function of temperature were recorded with samples (100～300 mg) spread evenly on the hot-plate (25 mmϕ) heated at the rate of about 75°C/min until the temperature reached 400°C.

RESULTS

1) Glow Curves of Natural Quartz and Utilization for an Accidental Dose

Natural quartz has received the radiation coming from some radioactive elements contained in itself and other natural radiation from the outside. Since some of this energy is stored at lattice imperfection as trapped electron, natural quartz shows glow signal, as is shown in Fig. 1, when it is heated. This glow curve exhibits three glow peaks, at approximately 110°C, 220°C and 310°C. The first peak has decayed out for the most part, while the second partially and the third have not practically. The peak at lower temperature region corresponds to electrons in shallow traps, whose life time is rather short. In the case of an accident the glow curve of the sample is complicated by the overlapping of two curves, one of which is natural glow curve and the other is from the accidental radiation. Recordings of the curve for natural quartz irradiated by Co^{60} gamma rays (1.5×10^3r/min) are shown in Fig. 1. One essential condition for the glow peak to be used as dosimeter in the thermoluminescence method is that thermoluminescence intensity is nearly zero prior to measurements. In view of the above fact, it is thought reasonable to assume that the first peak (110°C) is the most desirable peak for the estimation of the accidental dose. Nevertheless, from a consideration of the fact that the stored energy of this peak is lost quite

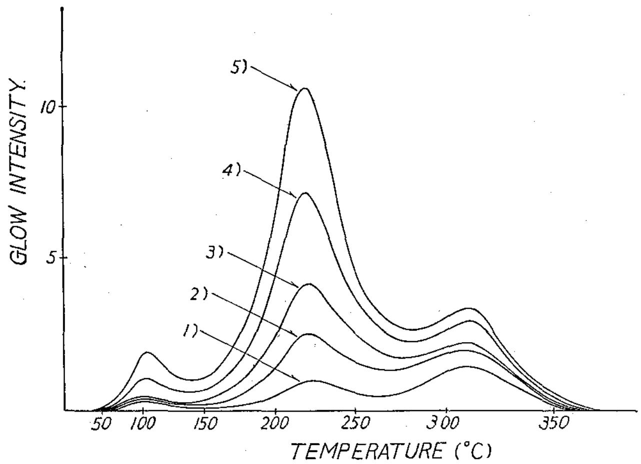

Fig. 1. Glow curve recordings of natural quartz for various doses : (1) natural samples ; (2) samples irradiated with Co^{60} for 1×10^3r ; (3) 2×10^3r ; (4) 5×10^3r ; (5) 1×10^4r.

rapidly merely on standing at room temperature, it seems most reasonable to conclude that the second peak (220°C) is useful for this purpose. The part of the glow curve above 200°C does not decay for seven months, as described in the previous report[8]. Also, this experiment indicate that the radiation received by these sample prior to the dose reading is equivalent to about 500r.

2) Normal Dosimetry

Crystallized quartz as thermoluminescence dosimeter have not high sensitivity at the state as it is, but its susceptibility for radio-thermoluminescence could be improved by the sample preparation reported herein-after. The experiments on

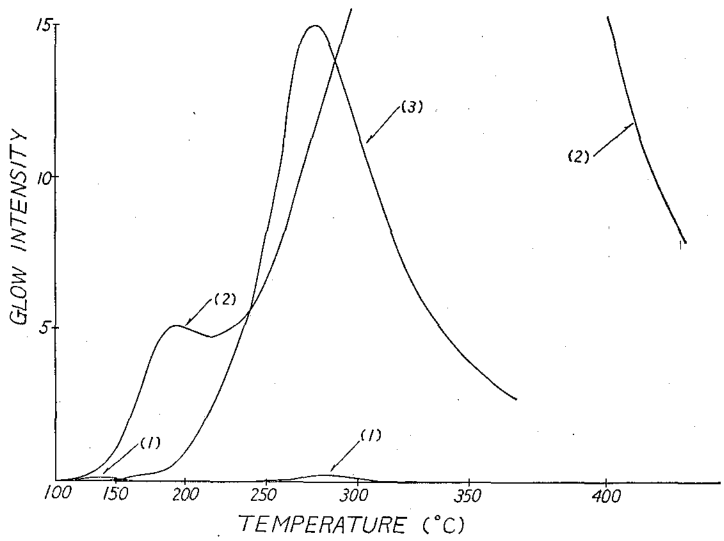

Fig. 2. Glow curve recordings of natural quartz irradiated with Co^{60} : (1) 1×10^3r ; (2) after cooling, 1×10^7r ; (3) after cooling over again, 1×10^3r.

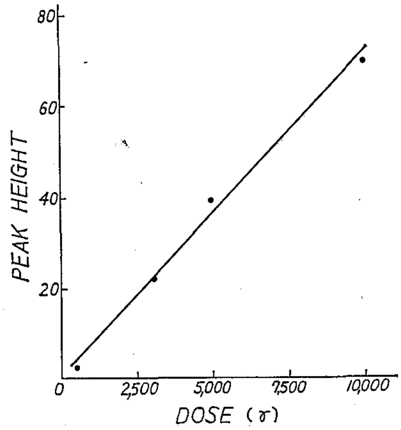

Fig. 3. Glow peak height of quartz preparated with the irradiation for various doses.

Brazilian quartz plate which showed in Fig. 2 were made in the following order; i) recording of the glow curve for the sample irradiated by Co^{60} gamma rays, 1×10^{3}r, ii) after cooling, recording of the curve coming from the irradiation of 1×10^{7}r gamma rays, iii) after cooling, recording of the one coming from 1×10^{3}r gamma rays over again. It becomes evident as the result that the susceptibility of the quartz for radio-thermoluminescence increases about four hundred times by the irradiation with Co^{60} gamma rays on a large scale (1×10^{7}r). This gain comes probably from the radiation damage of crystal which makes a contribution to the production of trapped centre. This dosimeter has also the advantage of low fading because of the high peak-temperature (280°C). Fig. 3 is a plot of the glow-peak heights of powdered quartz for the various dose, where they have linearity to the absorbed dose to 1×10^{4}r at least.

CONCLUSION

It has been found by the present experiment that the second glow peak of quartz is the most useful one for the dosimetry in the case of an accident. Nevertheless, concerning the dosimetry on the large scale of $1\times10^{5}\gamma$ or more, the higher temperature peaks are further to be examined because of the saturation of the glow signal at the second peak. The natural glow intensity of the second glow peak shows equivalent dose of about 500r and this is background in this measurements. The possibility to obtain above equivalent doses from the third peak intensity and then to raise the accuracy is now under study. In the case of normal dosimetry quartz irradiated with gamma rays (1×10^{7}r) exhibits the characteristic peak at 280°C and responds linearly with dose, at least over the range 2 to 1×10^{4}r. Tests of less than 2γ were not made on the present device. In the extent of these doses the above peak is accompanied by the glow signal resulting from thermal radiation at high temperature and this exerts a vicious influence upon an accurate measurement. As we have observed, many problems remains yet to be solved about quartz thermoluminescence dosimeter, but it was concluded that quartz was useful substance for dosimetry.

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